Measuring Time

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Measuring Time

Improving Project Performance Using Earned Value Management

Springer

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The only reason for time is so that everything doesn't happen at once.

Albert Einstein

Preface

Project scheduling began as a research track within the mathematical field of Operations Research in order to mathematically determine start and finish times of project activities subject to precedence and resource constraints while optimizing a certain project objective (such as lead-time minimization, cash-flow optimization, etc.). The initial research done in the late 1950s mainly focused on network based techniques such as CPM (Critical Path Method) and PERT (Programme Evaluation and Review Technique) which are still widely recognized as important project management tools and techniques.

From this moment on, a substantial amount of research has been carried out covering various areas of project scheduling (e.g. time scheduling, resource scheduling, cost scheduling). Today the project scheduling research continues to grow in the variety of its theoretical models, in its magnitude and in its application. While the research has expanded over the last decennia, leading to project scheduling models with deterministic and stochastic characteristics, single- and multi-mode execution activities, single and multiple objectives, and a wide variety of resource assumptions, the practitioners and software tools mainly stick with the often basic project scheduling principles. This can probably be explained by the limited capability of a project schedule to cope with the uncertainty that characterizes the real life execution of the project. Indeed, the benefits of a resource-constrained project schedule have been questioned by many practitioners, and the effort someone puts into the development of a project schedule is often not in line with the benefits. Moreover, "a project schedule will change anyway due to circumstances" is often a widely used excuse to skip this important step in the project life cycle.

Nevertheless, project scheduling and project control have always been topics of interest to me ever since the research performed in my PhD period. In order to appreciate the importance of a project schedule, it should be generally accepted that the usability of a project schedule is rather limited and only acts as a point of reference in the project life cycle. Consequently, a project schedule should especially be considered as nothing more than a predictive model that can be used for resource efficiency calculations, time and cost risk analysis, project tracking and performance measurement, and so on. Throughout the years of study, both in an academic set-

ting and in a more consultancy oriented environment, I discovered that the use of a baseline schedule is of crucial importance for project tracking, project performance measurement and schedule risk analysis. This idea silently brought me to earned value management (EVM) and arose my attention to the recent research done on this topic. The contacts and joint research interest I shared with Stephan Vandevoorde since many years, the meetings with Walt Lipke and Kym Henderson in London and the start-up of our company OR-AS together with Tom Van Acker brought everything in an acceleration. Since then, I continued doing research on fictitious and practical projects using earned value management for which the main results are written and summarized throughout the various chapters of this book.

Scope

In writing this book, I had no intention whatsoever to compete with the current excellent books of references about earned value management. Instead, the aim of this book is to throw a critical eye on the existing and newly developed techniques on EVM that measure and forecast the duration of a project. More precisely, the scope of this book can be summarized as follows:

- An overview: The book brings an overview of the common and often confusing terminology of earned value management. In this respect, many parts of this book are no more than a careful collection of statements, conclusions and results on project duration forecasting summarized from the academic and popular press.
- Formulas: The book focuses on the often simple calculations behind EVM systems rather than on the implementation details, the advantages and disadvantages and the possible impediments of these systems in practice. During the many consultancy projects, I discovered that, maybe due to the simplicity of many EVM calculations, the EVM metrics are often misunderstood or used and interpreted in a wrong way. In presenting many example calculations on small fictitious projects, I aim to bring clarity on this issue by allowing the reader to calculate along with me.
- Based on academic research: Many parts of this book are the results of academic research at Ghent University (Belgium) and Vlerick Leuven Gent Management School (Belgium). Hence, it offers a critical view on existing as well as novel EVM approaches by testing many alternative methods on a very diverse set of artificial project data that is used throughout many other, non-EVM research applications. The reader will often be referred to the current state-of-the-art literature and I truly hope that these references make the less popular academic literature a little bit more accessible to the broad audience.
- Inspired by practice: Most, if not all, results of this book are based on practical illustrations in companies, numerous discussions with colleagues and friends in charge of managing projects and by an overwhelming amount of (often virtual) discussions with project management practitioners.
- Limitations: The scope is restricted to a study on duration forecasting of a project, and hence, excludes the overwhelming amount of literature and work done on cost forecasting. The latter has been extensively investigated by, among many

others, David S. Christenson (for more information, visit the earned value bibliography[1]).

- Novel non-proven concepts: This book clearly focuses on recent research trends in earned value based duration forecasting and often brings newly developed concepts that are only recently discussed in the popular research press. It is not the intention to favor or reject any of these novel methods, but rather to (try to) bring an objective opinion by testing alternative approaches on the same project data. In this respect, the book can be used as a guideline for practitioners, and can be considered as a modest attempt to objectively compare alternative or competing EVM forecasting metrics, while keeping in mind that the ultimate truth will not be given by the formulas and simulations presented in this book.

Acknowledgements and authors

I am indebted to many people who have helped me in writing this book. First, I want to express my gratitude to Tom Van Acker (OR-AS) and Stephan Vandevoorde (Fabricom Airport Systems). Back to 2003, Stephan launched the idea to critically review the existing EVM methods in order to be able to see the bunch by the trees. Since then, he kept the research going throughout the years by guiding the many fruitful e-mail discussions between various EVM practitioners in Europe, US and Australia. Together with Tom, we have programmed our project scheduler ProTrack which is presented in chapter 7 of this book. After two years of weekend discussions and nights of programming troubles, we are proud on both our excellent cooperation and the product ProTrack that is the result of it. I am also much indebted to Walt Lipke and Kym Henderson for the many virtual and real meetings we had during the past several years, and to Ray Stratton for his quick and valuable comments on parts of this book. A special thanks goes to Broos Maenhout who has carefully read and recalculated all mathematical details of the chapters. Last but certainly not least, my sincere thanks goes to my family, especially Gaëtane for carefully reading and editing all chapters of this book, and Joyce and Thierry for their patience and their never-ending support.

The research discussed in the chapters of this book are obviously based on the common knowledge discussed throughout the literature. I want to express my gratitude to many authors that have written something in the field of project tracking in general and earned value in particular. In the remaining of this preface, I want to particularly mention a number of sources (both books and internet sites) that were helpful to me during the research project of this book. Obviously, this list does not contain an exhaustive summary of interesting references, but rather serves as a limited illustrative collection of sources useful to me and hopefully to the reader of this book.

References

Excellent books on earned value management have been reported in the literature. The books mentioned below belong to my favorites and deserve a note of

[1] www.suu.edu/faculty/christensend/ev-bib.html

attention since they are not all explicitly mentioned throughout the remainder of this book.

- Earned Value Project Management, 3rd Edition by Quentin W. Fleming and Joel M. Koppelman
- Practice Standard For Earned Value Management by the Project Management Institute
- Using Earned Value: A Project Manager's Guide by Alan Web
- Earned Value Management Using Microsoft Office Project: A Guide for Managing Any Size Project Effectively by Sham Dayal
- The Earned Value Management Maturity Model by Ray W. Stratton
- Earned Value Management by Roland Wanner
- Performance-Based Earned Value (Practitioners) by Paul Solomon and Ralph Young
- A Practical Guide to Earned Value Project Management by Charles I. Budd
- EVM Demystified: An Easy Guide for the Practical Use of Earned Value Management by Esther Burgess and Ruth Mullany
- Integrated Cost and Schedule Control in Project Management by Ursula Kuehn

Interesting sites

I particularly want to mention three interesting sites:

- www.earnedschedule.com: This site has been developed by Walt Lipke and is *the* site where you can find the latest developments and news about the progress in earned schedule. The site brings you the recent presentations and publications in the Measurable News and other journals and provides links to interesting contacts. With more than 13,000 hits per month in 2007, only one year after its introduction, the site can be considered as an enormous success.
- www.or-as.be: This is the site of our company OR-AS and is relevant for the reader for two main reasons. First, the reader can freely download all data files used in the simulation studies of chapters 4, 5 and 6. Moreover, the site also directs you to the software tool ProTrack which is the first and, to the best of our knowledge, only software tool which incorporates earned schedule in a traditional scheduling environment. Have fun!
- www.pmi-belgium.org: Being a Belgian citizen and having a professional career of more than 10 years in project management and scheduling naturally brings me to the Belgian chapter of the Project Management Institute (PMI) website (www.pmi.org). I want to use this opportunity to mention and promote the Belgian chapter of PMI, since many of the voluntary people have stimulated me in my research and in writing this book. Not only the financial support, but also the flow acceleration in the earned schedule interest after the chapter meeting of June 12^{th}, 2007, have motivated me to continue the research and to write this summary book.

Awards

On June 12^{th}, 2007, the research topic described in this book was awarded the Research Collaboration Fund by PMI Belgium. The introduction of this award was to

promote Belgian project management research, to translate results into white papers, available to all PMI members and to promote PMI Belgium outside the borders.

On November 11th, 2008, the research results have been awarded on the 22nd IPMA World Congress held in Rome (Italy). The IPMA Research Awards aim to promote excellent research to enhance project management. With these annual awards, IPMA recognizes recent outstanding contributions to the development of the discipline and profession project management through professionally conducted research. The award nomination announcement is posted on the IPMA website (www.ipma.ch) and a more detailed research description is available on www.or-as.be.

Ghent, January 2009 *Mario Vanhoucke*

Introduction

Earned Value Management systems have been setup to deal with the complex task of controlling and adjusting the baseline project schedule during execution, taking into account project scope, timed delivery and total project budget. It is a well-known and generally accepted management system that integrates cost, schedule and technical performance and allows the calculation of cost and schedule variances and performance indices and forecasts of project cost and schedule duration. The earned value method provides early indications of project performance to highlight the need for eventual corrective actions.

Although numerous excellent books and papers have been written to summarize various aspects of Earned Value Management, I believe that this book is unique in its kind and highlights earned value in a way that is different from the approach taken in any other traditional EVM book. This book is not an introductory book to EVM, nor a tutorial book on how to implement an EVM system in a company. Instead, it can be considered as a supplement on top of many other excellent books and hence, a basic knowledge about earned value will be considered as a given. I believe that this book differs in two aspects on the traditional EVM books, as follows:

1. Although earned value management systems have been proven to provide reliable estimates for the follow-up of cost performance within certain project assumptions, they often fail to predict the total duration of the project. Earned value management was originally developed for cost management and has not widely been used for forecasting a project's duration. However, recent research trends show an increase of interest to use performance indicators for predicting the total project duration. This book is a summary of a large research study that aims at validating EVM methods to forecast the total duration of a project.
2. Earned value has always been the domain of the practitioner who is in charge of managing and controlling projects. Hence, little or no effort has been done to critically analyze the behavior of EVM calculations for a wide set of very diverse project networks. This book takes a more academic approach and tests the behavior of EVM metrics on a large set of artificial data rather than on a

small sample of real data. The results on real data used in chapter 3 serve as an illustration and not as a proof of validity or general conclusion.

The book consists of eight chapters which can be briefly summarized along the following lines.

Chapter 1 gives an overview of the common and often confusing terminology of earned value management. The purpose of this chapter is twofold. First, it compares the classic earned value performance indicators SV (Schedule Variance) and SPI (Schedule Performance Index) with the newly developed earned schedule performance indicators SV(t) and SPI(t). Next, it presents a generic schedule forecasting formula applicable in different project situations and compares three methods from literature to forecast the total project duration.

Chapter 2 critically reviews and tests a novel EVM extension, the so-called p-factor approach, to measure schedule adherence based on the traditional earned value metrics. The purpose of this chapter is twofold. First, the chapter discusses the relevance of the p-factor for the detection of project impediments and/or portions of work performed under risk, based on the calculation of the traditional earned value metrics. Second, the chapter critically discusses the contribution of the p-factor to modify and improve the accuracy of the forecasts along the life of the project. Simulation results will be presented in the simulation study of chapter 4.

Chapter 3 presents a case study for three real life projects at Fabricom Airport Systems. This chapter serves as an illustration for the various concepts introduced in the previous chapters. To the best of my knowledge, this is the first time the earned schedule concept, discussed in chapter 1, is used in a practical setting in Belgium.

Chapter 4 extensively reviews and evaluates earned value based methods to forecast the total project duration based on a large Monte-Carlo simulation study. The simulation carefully controls the level of uncertainty in the project, the influence of the project network structure on the accuracy of the forecasts, and the time horizon where the earned value based measures provide accurate and reliable results. It assumes a project setting where project activities and precedence relations are known in advance and does not consider fundamentally unforeseeable events and/or unknown interactions among various actions that might cause entirely unexpected effects in different project parts. This is the first study that investigates the potential of a recently developed method, the earned schedule method, which improves the connection between earned value metrics and the project duration forecasts.

Chapter 5 sheds light on another time dimension of project management. The chapter reviews the basic calculations to measure the sensitivity of an individual activity of the project network. The relation between forecast accuracy and project sensitivity is discussed in detail. This chapter investigates the ability of activity sensitivity information to improve the project tracking process and the possible corrective actions needed in case of problems or opportunities. .

Chapter 6 presents a last simulation study that combines the results of the two previous chapters. More precisely, it validates and compares two alternative tracking methods and measures their efficiency on the total project objective. A top-down project tracking method relies on the EVM results of chapter 4 while a bottom-up tracking approach uses the results learnt from chapter 5.

Chapter 7 presents the new software tool ProTrack developed by OR-AS that integrates all research discussed throughout the various chapters in this book. Although the chapter does not enumerate all detailed features of the software, it gives an overview of the project scheduling and tracking approach and the different engines (project generation, simulation and time forecasting engines) that have been developed and discussed in this book.

Chapter 8 gives an overview of the various chapters presented throughout this book, and reviews the results from the four simulation studies from a project tracking point of view. More precisely, the conclusion clearly reviews the difference between top-down and bottom-up project tracking, and highlights the role of earned value management and schedule risk analysis in the two alternative tracking methods.

Most of the material and research has been published elsewhere. The work presented in chapter 1 can be found in the overview paper published by the International Journal of Project Management (Vandevoorde and Vanhoucke, 2006). Parts of the simulation study of chapter 4 have been published in the Measurable News (Vanhoucke and Vandevoorde, 2007a, 2008, 2009) and the Journal of the Operational Research Society (Vanhoucke and Vandevoorde, 2007b). Overview articles can be found in Vanhoucke (2008c,e, 2009). Other chapters or parts of chapters are still under submission (Vanhoucke, 2008a,b,d) and will hopefully be published soon in the academic literature.

Contents

List of Acronyms

A	
AC	Actual Cost
ACWP	Actual Cost of Work Performed
AD	Actual Duration
	Activity Distribution
ALAP	As-Late-As-Possible
AoA	Activity-on-the-Arc
AoN	Activity-on-the-Node
ASAP	As-Soon-As-Possible
AT	Actual Time
B	
BAC	Budget At Completion
BCWP	Budgeted Cost of Work Performed
BCWS	Budgeted Cost of Work Scheduled
BU-SRA	Bottom-up project tracking using Schedule Risk Analysis
C	
CI	Complexity Index
	Criticality Index
CNC	Coefficient of Network Complexity
CPM	Critical Path Method
CPI	Cost Performance Index
CPI(e)	Effective Cost Performance Index
CR	Critical Ratio
CRI	Cruciality Index
CV	Cost Variance
CV(e)	Effective Cost Variance
D	
d_i	Activity Duration

d_i^b	Activity duration (baseline schedule)
DFT	Due Finish Time
DSM	Design Structure Matrix
DST	Due Start Time

E

EAC	Expected At Completion (cost)
EAC(t)	Expected At Completion (time)
$\text{EAC(t)}_{\text{PV}}$	EAC(t) using the Planned Value method
$\text{EAC(t)}_{\text{ED}}$	EAC(t) using the Earned Duration method
$\text{EAC(t)}_{\text{ES}}$	EAC(t) using the Earned Schedule method
ED	Earned Duration
EDAC	Estimate of Duration At Completion
ES	Earned Schedule
EV	Earned Value
EVM	Earned Value Management
ESS	Earliest Start Schedule
E(x)	Expected value of variable x
ES(e)	Effective Earned Schedule
EV(e)	Effective Earned Value
EV(p)	Risk-free Earned Value
EV(r)	Risk-sensitive Earned Value

F

FF	Finish-Finish
FS	Finish-Start

G

GERT	Graphical Evaluation and Review Technique

I

IEAC(t)	Independent Estimate at Completion (time)
IEDAC	Independent Estimate of Duration At Completion

L

LA	Length of Arcs
LFT	Locked Finish Time
LRS	Latest Revised Schedule
LSS	Latest Start Schedule
LST	Locked Start Time

M

MAPE	Mean Absolute Percentage Error
MPE	Mean Percentage Error

N

N	Set of activities in a project network
n	Net of activities in a project network
n'_l	Number of arcs in a project network with length l
nrs	Number of simulation runs

O

OR-AS	Operations Research - Applications and Solutions
OS	Order Strength

P

PB	Project Buffer
PC	Percentage Completed
PCWR	Planned Cost of Work Remaining
PD	Planned Duration
PDWR	Planned Duration of Work Remaining
PERT	Programme Evaluation and Review Technique
PF	Performance Factor
P_i	Set of immediate predecessors of activity i
PLC	Project Life Cycle
PL_i	Progressive level of an activity i
PMBOK	Project Management Body Of Knowledge
PMI	Project Management Institute
ProTrack	Project Tracking (software tool)
PV	Planned Value
PV_{rate}	Planned Value Rate
PV_t	Planned Value at time t

R

RC	Remaining Cost
RD	Real Duration
RD^{no}	Real project duration without any corrective action
RD^{yes}	Real project duration with threshold triggered corrective action
RL_i	Regressive Level of activity i
RFT	Ready Finish Time
RST	Ready Start Time
R%	Estimated portion of EV(r) that is usable and requires no rework

S

SCI	Schedule Cost Index
SCI(t)	Schedule Cost Index (time)
SF	Start-Finish
S_i	Set of immediate successors of activity i